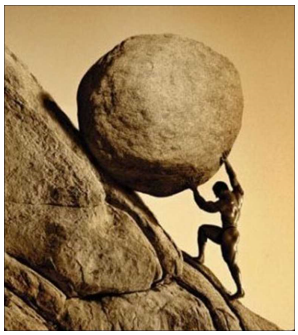
7.1 – Work Done by Constant Force



Name On Booklets!

Who's this guy?

0. Intro Question: What is Your Definition of Work?

Work in Physics

Work equals force times distance:

$W = F \cdot d$	F = force (N) d = distance (m)

If force acts at an angle:

$$W = F(\cos\theta)d$$

Terrible Physics Joke:

Since $W = Fd$,

and $F = ma$,

$W = mad$, so why do it?

Work (Energy) Units

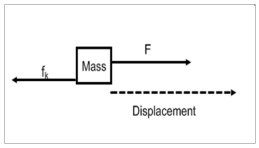
Work is Newtons times meters, so the resulting unit is a Newton-meter, or a 'Joule' (J), after James Prescott Joule, a pioneer of thermodynamics and studies of energy/mechanical relations.

For perspective, lifting 100 g up 1 meter requires roughly one joule of energy (100g mass demo).

Unit derivation: $J = N \times m = \frac{kg \cdot m}{s^2} \times m = \frac{kg \cdot m^2}{s^2}$

Work Perspectives

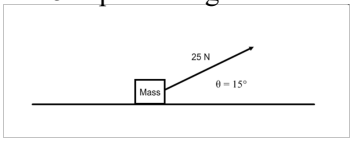
If force acts in the opposite direction as displacement (like friction), then work done by that force is negative.



$$W_{friction} = F(\cos 180^\circ)d = -Fd$$

1. Example

How much work is done moving an object 16 meters at constant velocity on level ground with 25 N of force at a 15° upward angle?



$$W = F(\cos\theta)d = 25\,N(\cos 15^{\circ})16m = 390\,J$$

2. Example

A 150 kg box is lifted straight up from the deck of a ship 15 meters with constant velocity.

What force is moving the box, and what is the work done by that force?

Make an FBD to assist your understanding.

2. Example

FBD:

Tension moves the box: tension is equal and opposite to the force of gravity.

$$W = F \bullet d$$
$$W = F_T \bullet d = m \bullet g \bullet d$$
$$= 150\,kg \bullet 9.81\,m/s^2 \bullet 15\,m$$
$$= 22,000\,J$$
$$= 22\,kJ$$

3. Follow up Question

What work was done by gravity in the previous problem?

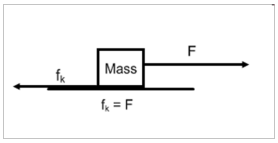
The force of gravity has the same magnitude as the force of tension, but is acting opposite the direction of motion:

$$W = F \bullet d$$
$$W = -m \bullet g \bullet d$$
$$= -150\,kg \bullet 9.81\,m/s^2 \bullet 15\,m$$
$$= -22\,kJ$$

Net Work

Definition: The sum of all work done by all forces acting on an object.

In a situation of constant velocity (no net force), the net work will equal zero.



4. Example

A 0.75 kg box slides 1.28 m down a 20.° incline at constant velocity.

A. What's the work done on the block by gravity?

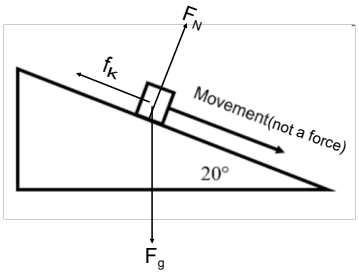
B. What's the net work done on the block?

C. How would net work change if the box were accelerating?

4.A Answer: Slide 1

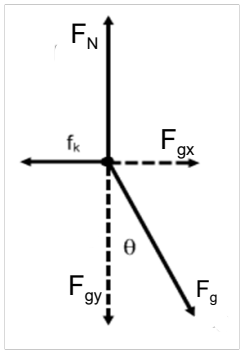
List your variables and make a sketch:

m = 0.75 kg
d = 1.28 m
θ = 20.0°
v = constant



4.A Answer: Slide 2

Make an FBD to help visualize forces.



4.A Answer: Slide 3

Determine the work producing force (F_{gx}).

$F_{gx} = mg \sin\theta$

$= 0.75\ kg \times 9.81\ m/s^2 \times \sin 20^o$

$= 2.52\ N$

Plug the force of gravity (x-component) into the work equation:

$$W = F_{gx} \bullet d$$

$$= 2.52\,N \bullet 1.28\,m = 3.23\,J$$

4.B Answer

B. Net work done – the sum of all work done by all forces: we must find the work done by friction. Since the force of friction exactly opposes applied force (constant velocity):

$W_{friction} = -(f_k \times d)$

$= -(2.52\ N \times 1.28\ m) = -3.23\ J$

So: Net Work = $W_{gravity} + W_{friction}$

$= 3.23\ J + (-3.23\ J) = 0.0\ J$

4.C Answer

C. What if there were acceleration?

This implies a net force, from Newton's 2nd: $F_{net} = ma$.

$$F_{mg_x} > f_k$$

so:

$$\left|W_{mg_x}\right| > \left|W_{f_k}\right|$$

This will increase the amount of kinetic energy in the crate.

Homework:

Read 5.1 – 5.2 in your book
7.1 Problems in your Booklet
Due: next class